Distribution of H_2 in the Lunar Exosphere from LAMP Observations

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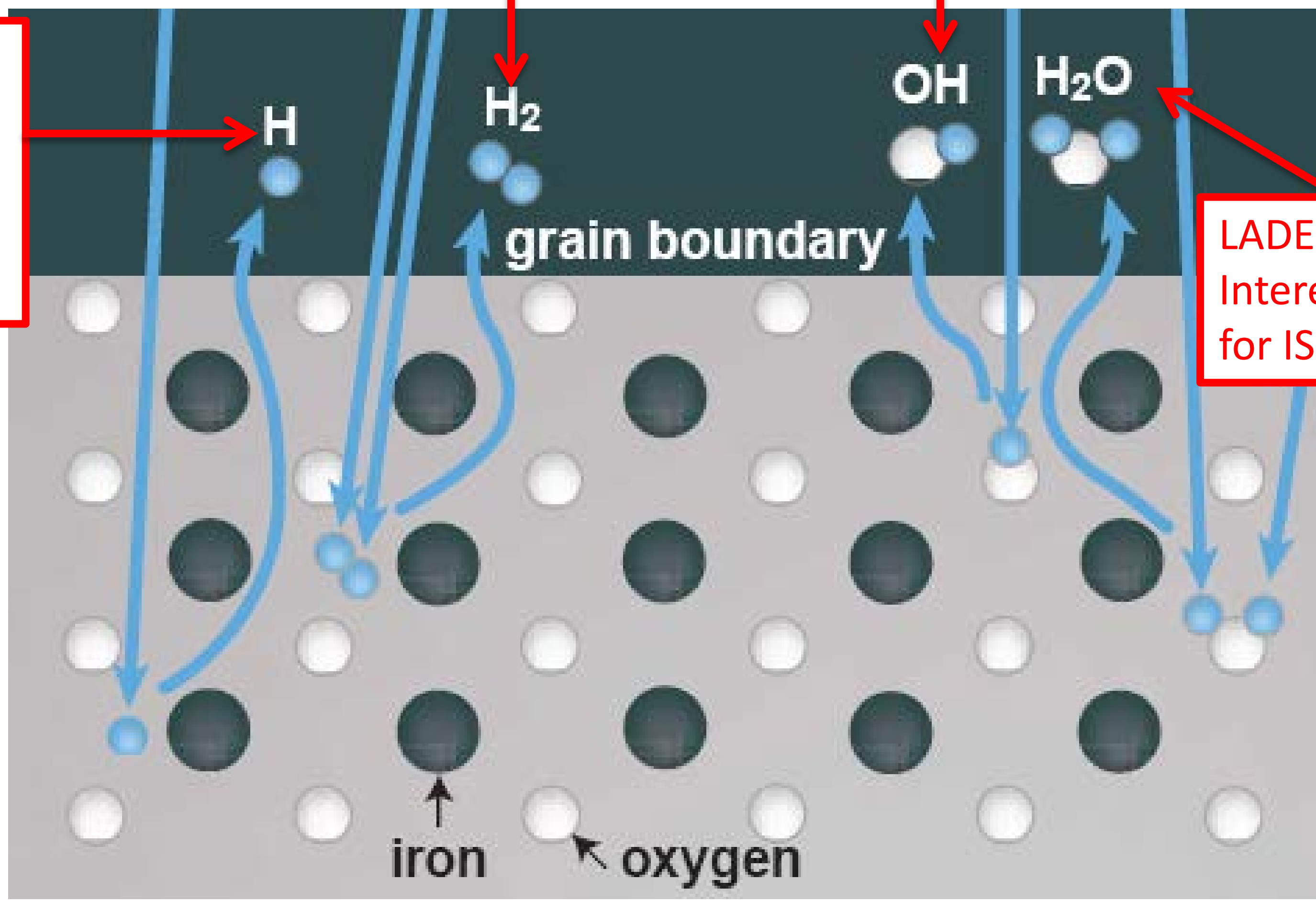
Conservation of solar wind H^+

LAMP: THIS WORK

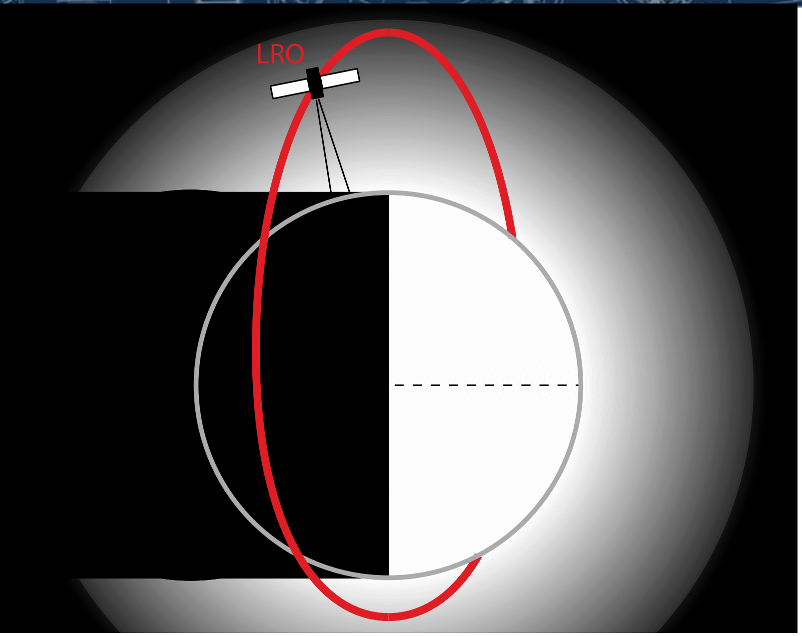
LADEE

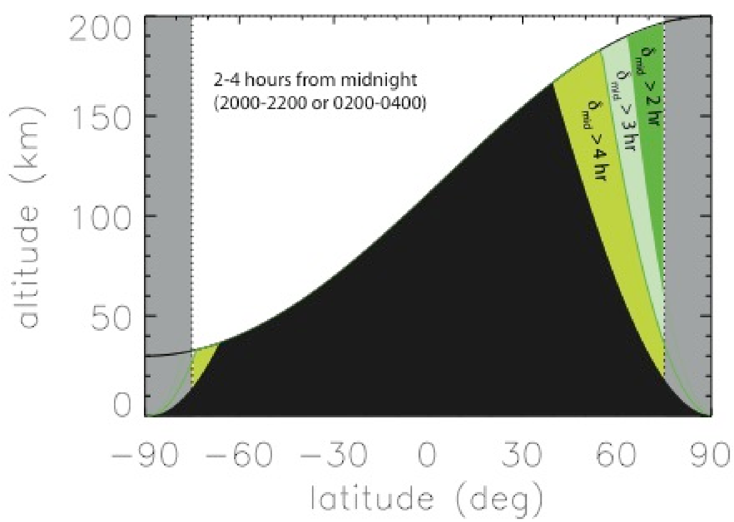
Measured H^+: (Kaguya , ARTEMIS);
H: (IBEX, Chandrayaan-1)

LADEE, Interesting for ISRU



LAMP Atmosphere Observations





- Lyman Alpha Mapping Project (LAMP)
  - FUV imaging spectrograph
  - 0.3° x 6° field of view
  - 570-1960 Å
  - Onboard LRO
- Nadir pointed
  - Illuminated atmosphere over dark surface
  - Limited to near-terminator "Twilight"
  - Polar regions for low β orbits
  - Entire nightside for β ~ 90°

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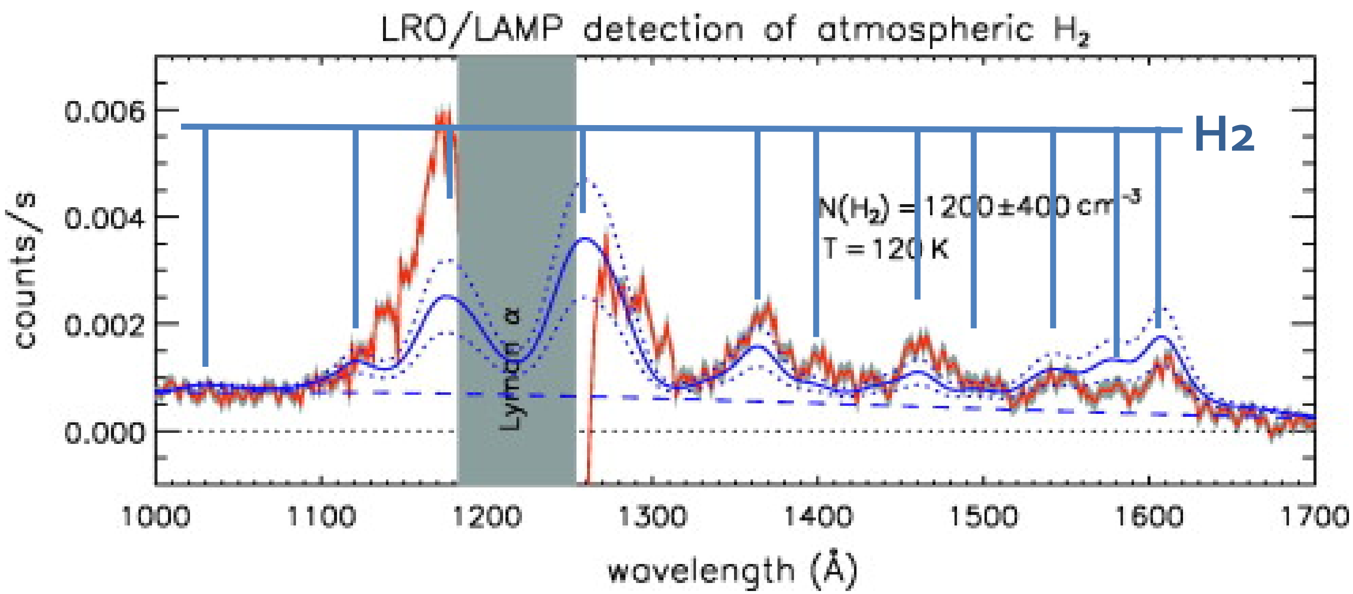
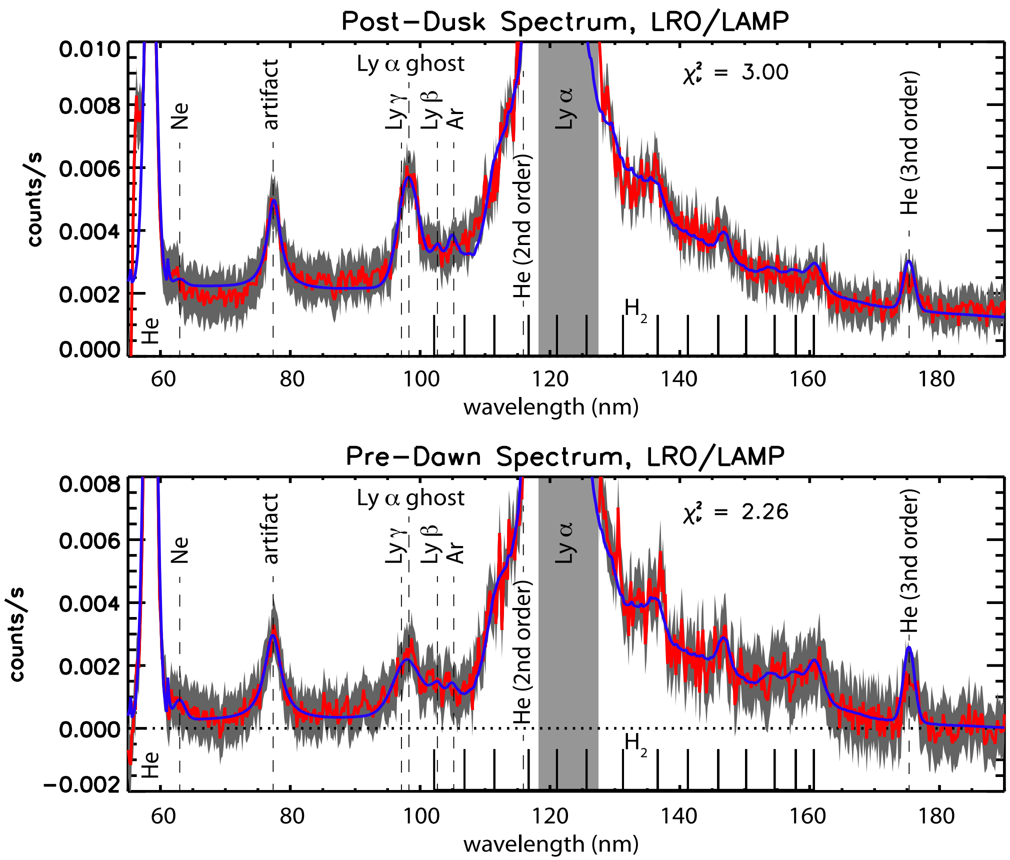
Initial H_2 Detection



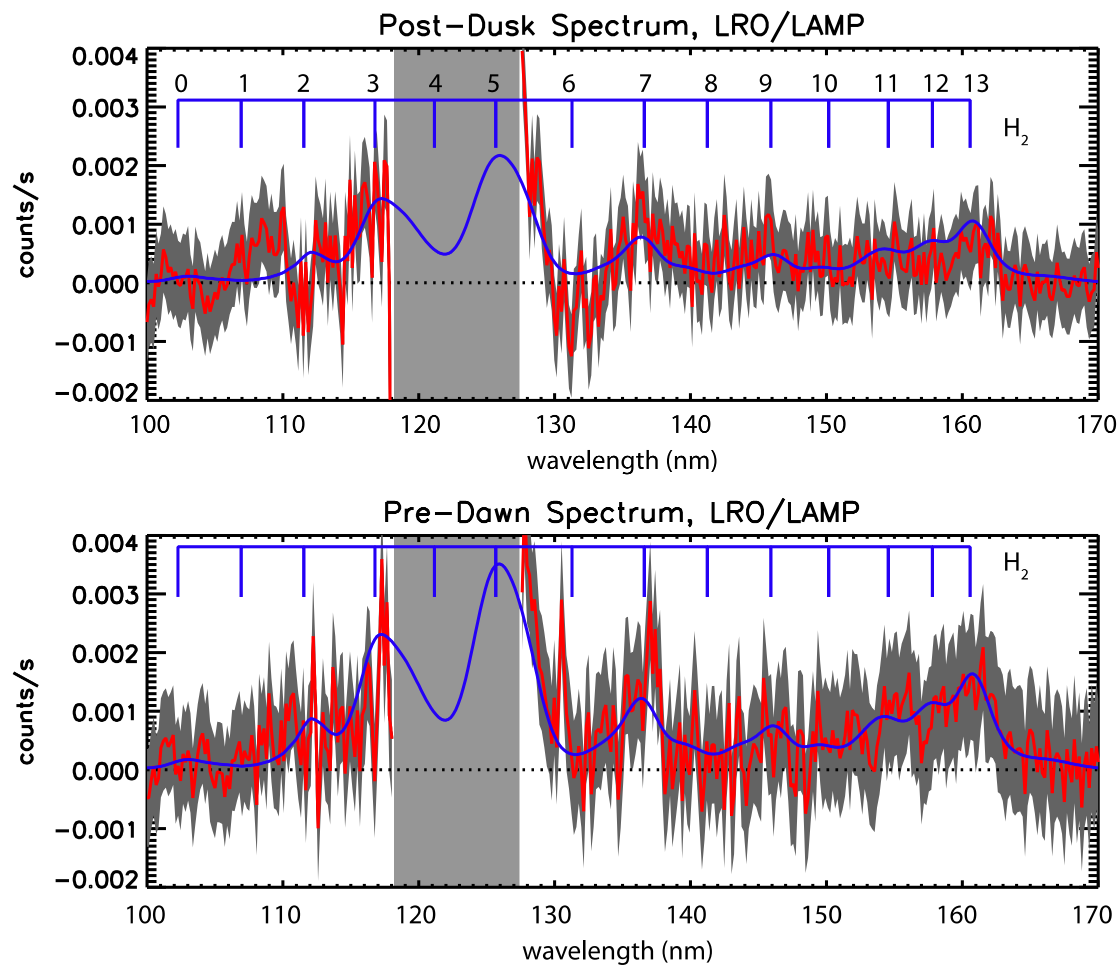
- **Stern et al., Icarus, 2013**
- Average “Twilight” Observation
  - High latitude, nightside
  - Residual: red, Fluorescence model: blue
  - Density 1200 cm^{-3} consistent w/ Apollo 17 UVS upper limit: <9000 cm^{-3}

Dawn/Dusk Spectra



- Coadd data
  - Latitude 35°-75°
  - Post-dusk (LT=18:22-19:18)
  - Or pre-dawn (LT=4:42-5:34)

Dawn/Dusk H_2 Spectra



- H_2 spectrum obtained by subtracting
  - Background
  - H (Lyman series)
  - He (multiple orders)
  - Ar, Ne
  - Known instrumental effects

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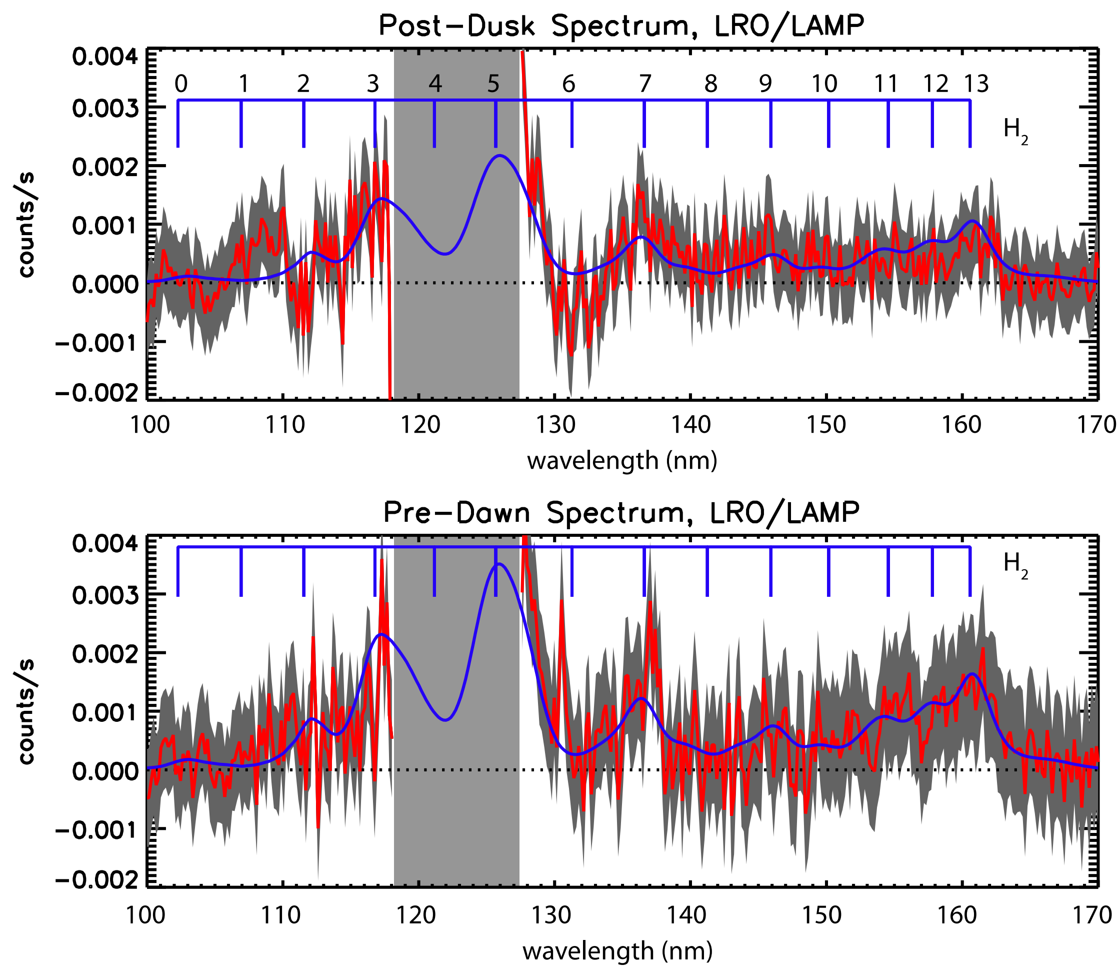
Dawn/Dusk H_2 Spectra

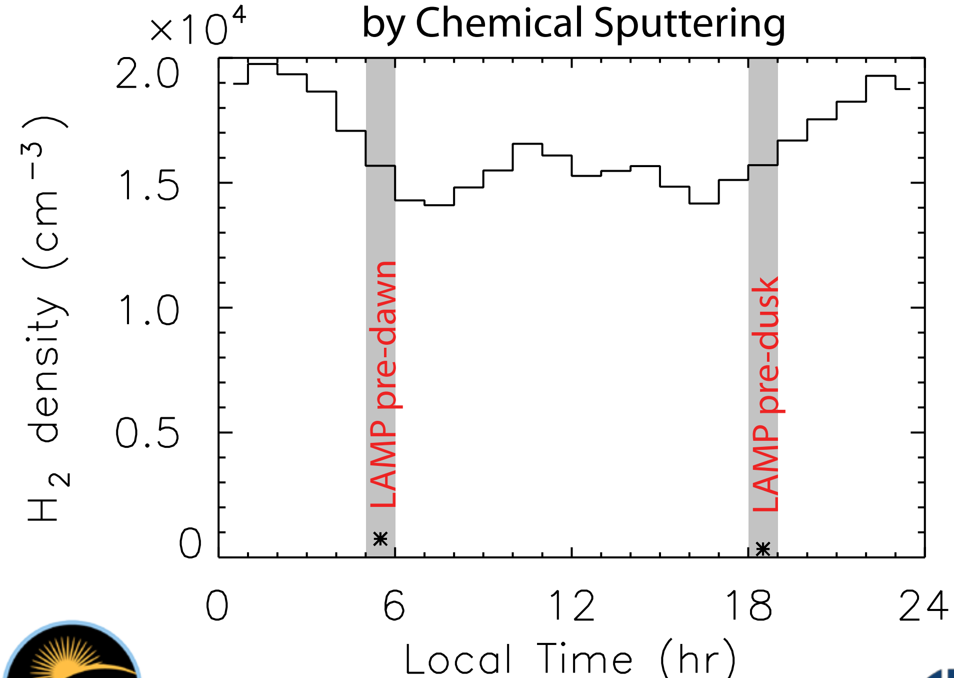


- Fit model of H_2 fluorescence
  - Lyman and Werner bands
- Dusk 410±130 cm^{-3}
- Dawn 690±170 cm^{-3}
- Enhanced H_2 is detected at dawn compared to dusk

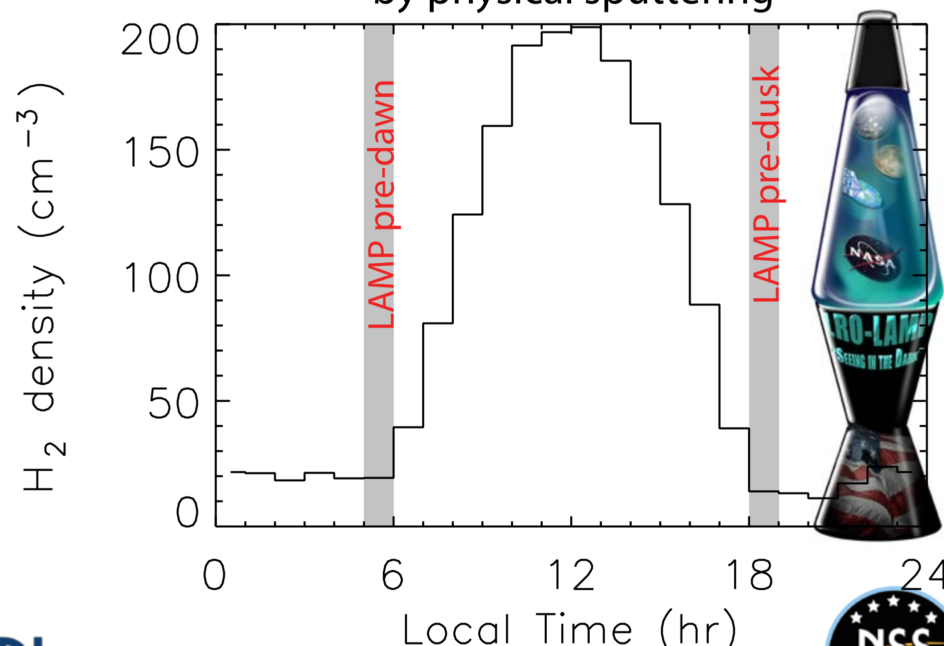
H_2 Model—Solar Wind Source

- Immediate diffusion of incident p^+ as H_2 does not reproduce a dawn/dusk asymmetry

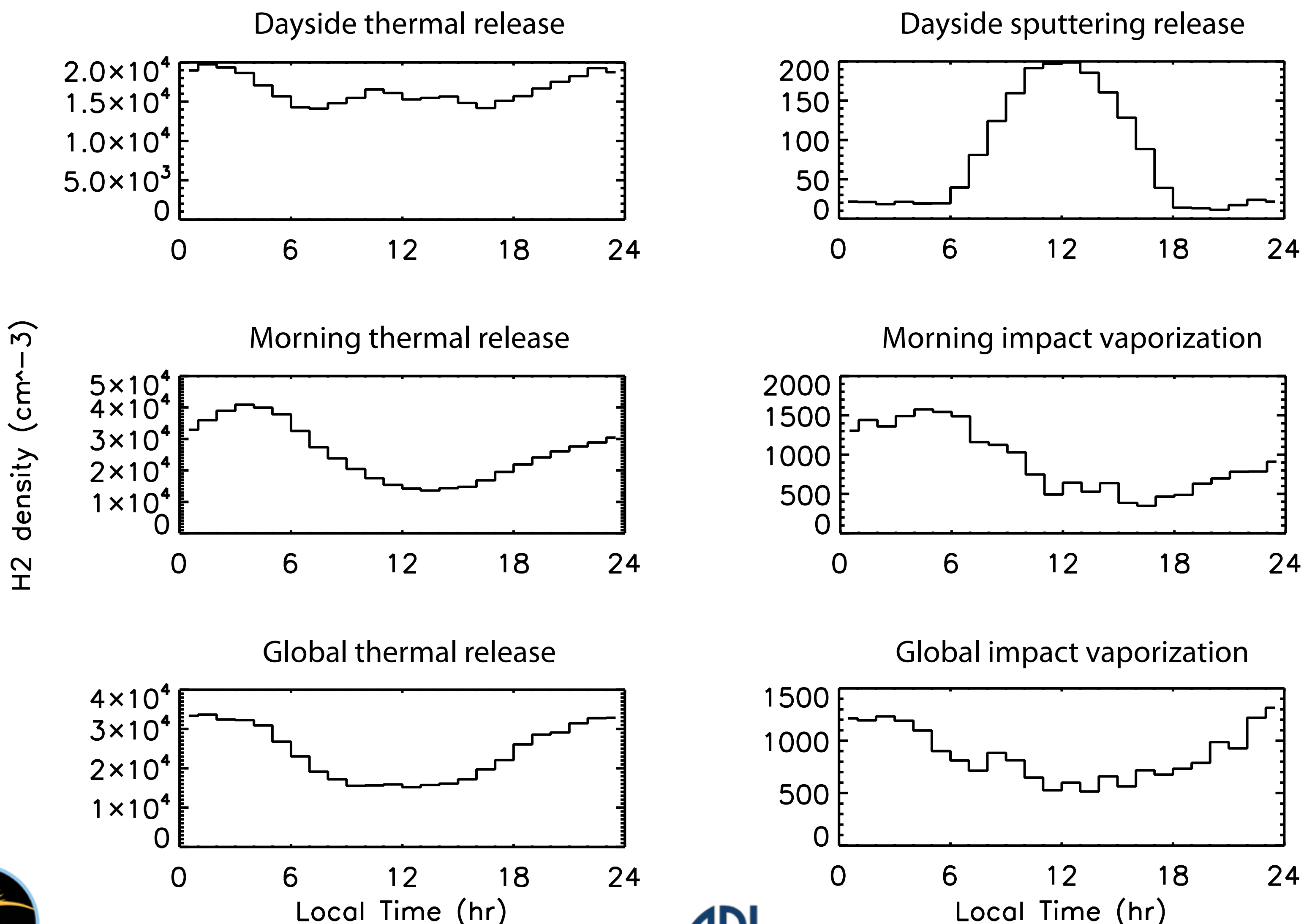
LOW ENERGY
100% solar wind, released as H_2
by Chemical Sputtering



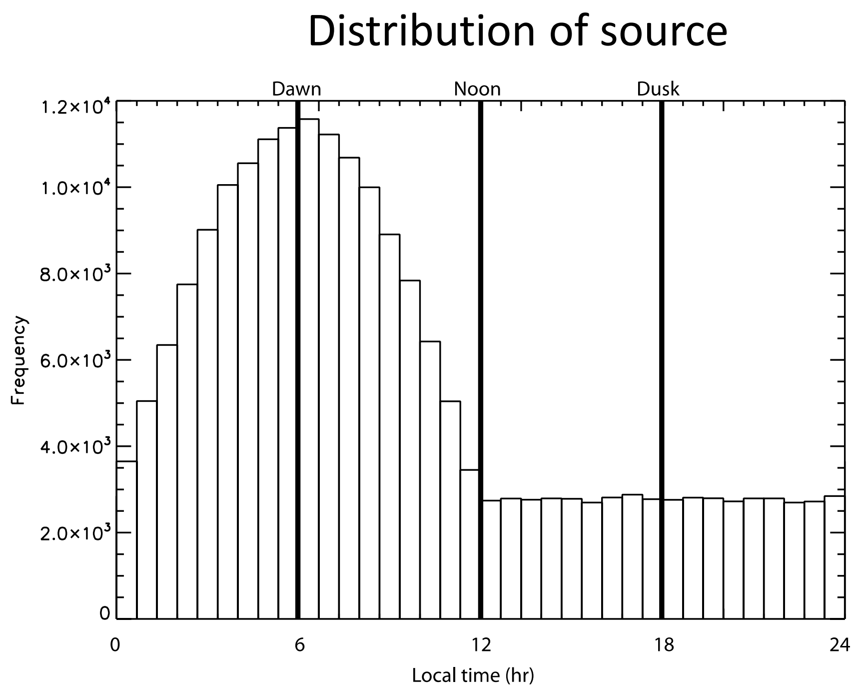
HIGH ENERGY
100% solar wind released as H_2
by physical sputtering



H_2 Model, Many Processes



H_2 Model—Micrometeoroid Release



- Global isotropic background
- Enhancement for morning hemisphere representing motion of Earth-Moon system sweeping into particles

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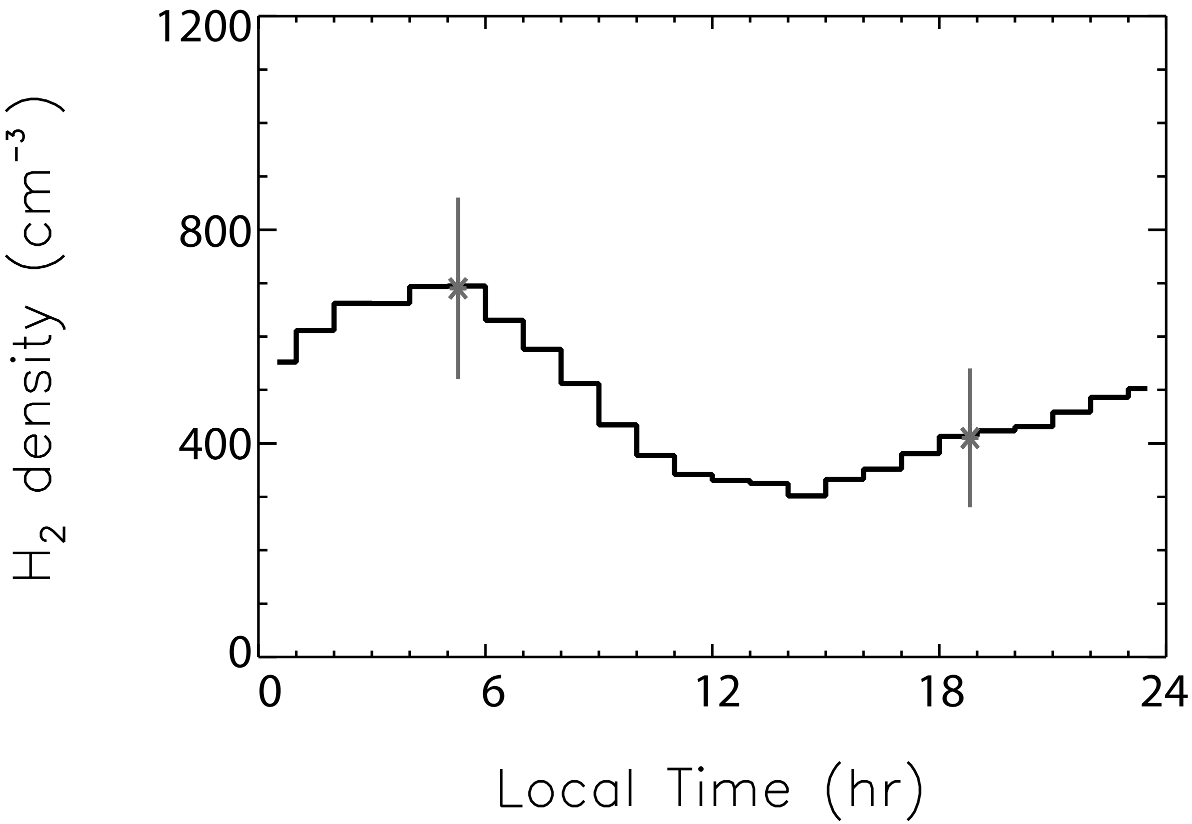
H_2 Model—Micrometeoroid Release

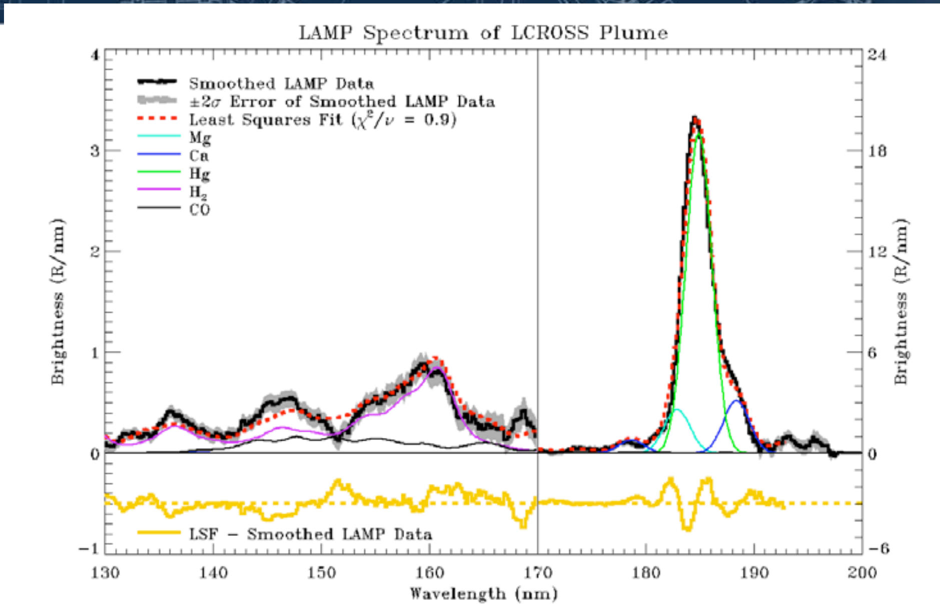


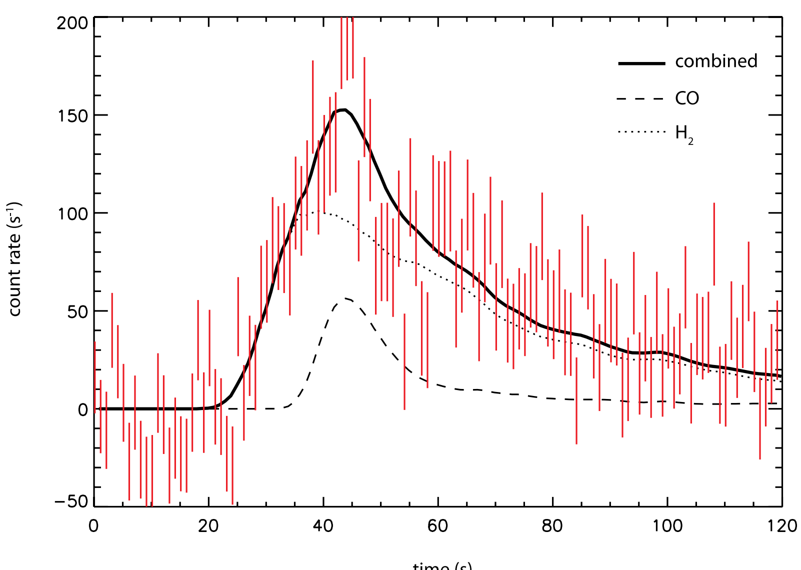
- Source centered on the dawn terminator reproduces the dawn/dusk asymmetry.
- Density consistent with 12% of solar wind (assuming T=1000 K)

Inventories of H_2

	Flux ($g\ cm^{-2}\ s^{-1}$)	Mass rate ($g\ s^{-1}$)	T=3000 K Efficiency that would produce 22 $g\ s^{-1}$	T=1000 K Efficiency that would produce 3 $g\ s^{-1}$
Micrometeoroid delivery	6.67×10^{-16}	250	8.8%	1.5%
Micrometeoroid release	1.77×10^{-15}	670	3.3%	0.6%
Solar wind delivery	3.34×10^{-16}	32	70%	12%

H_2 in the LCROSS Impact Vapor





Species	Observed (kg)	Mass released (kg)
H_2	1.33	117±16
CO	0.70	41±3
Ca	0.16	16±1
Mg	0.04	3.8±0.3
Hg	0.12	12.4±0.8

Gladstone et al., Science, 2010;
Hurley et al., JGR, 2012

Conclusions

- LAMP observes a dawn/dusk asymmetry in the distribution of H_2 in the lunar exosphere.
- Modeling shows:
  - An asymmetric source is required to reproduce a dawn-dusk asymmetry
  - Higher energy release mechanisms produce lower density for a given source rate
  - For T=1000 K, 3 g s^{-1} source rate needed to reproduce density
- Modeling of micrometeoroid vaporization of implanted hydrogen reproduces LAMP observations.
  - Steady state achieved with a source rate of a few 10s% conversion of solar wind (through subsequent impact vaporization).
  - Perhaps the H_2 observed in the LCROSS plume was analogously released.